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AVIATION AND AERONAUTICAL ENGINEERING

Bleriot 28-Passenger Airplane, Fitted with Four Hispano-Suiza 220 Hp. Engines
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VOLUME VII
Number 8

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SPECIAL FEATURES

DEVELOPMENT OF FRENCH NAVAL AVIATION
SUPPLY OF METEOROLOGICAL INFORMATION
ESTIMATING THE PERFORMANCE OF AN AIRPLANE
THE EFFICIENCY OF TANDEM PROPELLERS
INADEQUACY OF VISUAL INSPECTION IN KILN-DRYING

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CREW OF U. S. MARTIN "ROUND THE RIM FLYER"—Left to right: Colonel Hartz, Lieuts. L. A. Smith and E. E. Harman, Sergeants John Harding, Jr., and Jeremiah Tobias

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Cleveland	Washington	Eric Springer	350 Miles	2 hours, 58 min	14 hours
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NOVEMBER 15, 1919

AVIATION AND AERONAUTICAL ENGINEERING

VOL. VII. NO. 8

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INDEX TO CONTENTS

	PAGE
Editorials	339
The Development of French Naval Aviation	340
Electrical Timing Apparatus for Speed Tests	345
The Supply of Meteorological Information	346
Estimating Performance of an Airplane	349
The Influence of Water Injection on Engine Performance	350
Note on the Efficiency of Tandem Propellers	351
Inadequacy of Visual Inspection in Kiln-Drying	352
Study of Aerology in the Air Services	354
M I T Endowment Campaign	354
Computations of Airplane Climb	355

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AVIATION AND AERONAUTICAL ENGINEERING

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Vol. VII November 15, 1919 No. 8

THE policy of McCook Field, where the experimental work of the Air Service is done is so evidently towards excessive centralization that attention should be given it by those interested in American aeronautic development. At a time when our designers are trying to keep their work ahead of foreign aeronautical engineering, they find little practical encouragement from McCook Field. Aeronautic engineers of the best type such as Willard, Loening, Vought, Thomas, Gallaudet and others whose airplanes have been among the best in the world, are idle as far as the Army is concerned, while McCook Field is engaging foreign engineers to design airplanes for the American Air Service. Their employment by the United States War Department, while American engineers are struggling along without development work, is unfortunate.

If all the design, engineering and experimental work of the Army is to be centralized and the native industry become merely a reproductive agent of McCook Field, a protest should be made at once. If the achievements of the engineers at McCook Field had been great as compared with the private designers, it would not be as difficult a situation to face. But with all the huge expenditures, comparatively little of original work has been forthcoming.

With the American aviation industry at a standstill, twelve hundred men are at work at Dayton, many of them at very high salaries, and the plan of moving to Moraine City is constantly being brought up. If the indicated policy is continued American designers will have to look solely to the Navy or commercial aviation for encouragement and this country will face a situation where in a military emergency, it will have nothing but the limited productions of McCook Field for reproduction, rather than the products of the best American aeronautic engineers.

Fuels for High Compression Ratios

In a recent paper by E. W. Dean and Clarence Netzer publicity has been given to one of the most important pieces of research carried out during the war, by the cooperation of the Bureau of Mines, the Signal Corps, the Delco Laboratories and the Bureau of Standards, namely, the relation between the nature of the fuel employed in an internal combustion engine and the maximum compression ratio that can be maintained without interfering with smooth operation.

The Delco laboratories, first experimenting with an air-cooled engine adapted for operating on kerosene, found that the use of compression ratios above a certain value caused what was described as "the kerosene knock" or "pinking." With proper selection of fuel this "knock" could be avoided. It was this "knock" which at the time caused the general conviction that the compression ratios of airplane engines should be limited to the order of 5.4 to 1.

Very logically a similar process of selection was applied to aviation engine fuels. The chemical properties of the fuels were obviously more important than the physical properties of the fluid. Accordingly, samples of gasoline were obtained from different varieties of crude petroleum; various types of synthetic gasolines were obtained. Benzol, alcohol, cyclohexane were other fuels employed.

Tests were conducted in a single cylinder liberty engine, in which compression ratios could be varied from 5.3 to 1 up to 8.2 to 1.

The final result of the investigation was that "hecter" benzol, alcohol and a special alcohol-benzol-gasoline mixture showed only a slight tendency to knock under an 8.2 to 1 compression ratio.

On a Liberty 12 a mixture of 70% of cyclohexane and 30% of benzene, gave with a compression ratio of 7.2 favorable results both on the block and in the air, with perfectly smooth runs. Altitude laboratory tests showed a decided increase in power at all levels. Since one of the main difficulties in practical aeronautics is the employment of high compression ratios to keep down engine weight, the above results are very gratifying. The chemist has shown us a path, which has much promise.

Alloy Research

The division of Industrial Research, National Research Council announces the formation of an Alloys Research Association to conduct systematic research into fundamental questions affecting pure metals and alloys, both ferrous and non-ferrous.

The Association will invite its members to submit technical questions.

It is extraordinary how many questions an aviation member could ask, or in how many directions he could utilize both steel and aluminum alloys.

The work of the Association will be closely watched by the aeronautical industry insofar as it relates to a wider and more efficient utilization of metal in the component parts of aircraft.

The Development of French Naval Aviation

By John J. Ide, Lieut. (j.g.) U. S. N. R. F.

On August 2, 1914, the naval aircraft possessed by France consisted of exactly three Nieuport hydromonoplanes without spares. Such was the development during the war that at the signing of the armistice the French Navy had forty-four air stations and approximately one thousand machines.

During the war the principal function of the French Naval Aviation Service was to search for and attack enemy submarines. The aerial patrols carried out by seaplanes and air-

Fig 1 Nieuport Float Seaplane (1914)—100 H.P. Gnome

ships forced the German submarines to give the French coast a wider and wider berth as time went on. There is not one example of a convoy of merchant ships off the French coast having suffered when protected by an aerial escort, whereas numerous convoys were attacked successfully, both in daylight and at night, when protected merely by surface craft. To the continuous watch which naval aircraft maintained around the French coast and over the entire Mediterranean Sea is partially due the final failure of submarine warfare.

The activities of French seaplanes, however, were not confined to the areas mentioned above. Shortly after the beginning of hostilities, the one existing squadron of seaplanes was sent to Port Said and put into service with the British Army in Egypt. There they made long flights above the deserts to observe the movements of the Turkish Army in the regions of Mesopotamia and the Suez Canal.

One can easily imagine the difficulties of carrying out these flights when it is realized that distances of 100 mi., or more, inland over mountains 6000 ft. high were covered with *seaplanes*. The losses were considerable, but none of the personnel was injured in any of the forced landings.

Types of Aircraft Used

At the conclusion of the war, the heavier-than-aircraft

Fig 2. Nieuport Float Seaplane (1918)—100 H.P. Gnome

utilized by the French Navy fell under three heads: 1 Airplanes. 2. Float Seaplanes. 3 Boat Seaplanes.

Of the airplanes, few in number, there is little to be said. They were similar to the scouting machines used over land, with the addition of flotation gear permitting them to alight on the sea. These machines cannot take off from the water; they have to be hauled on board the mother ships. France, unlike England, has not developed special ships permitting airplanes to land and take off from their decks.

In regard to seaplanes, the float type was at first used almost exclusively. The 1914 type Nieuport monoplanes (Figs 1 and 2) were very satisfactory, but they had to be abandoned, as the firm soon devoted all its energies to military machines. Gradually, except for pursuit work, float seaplanes were given up in favor of boat seaplanes, the latter type being considered

CHARACTERISTICS OF PRINCIPAL TYPES OF FRENCH SERVICE SEAPLANES

Make Type	Hull or Floats	No. of Seats	Engines No.	Engines HP	Engines Make	Span Upper Wing Ft.	Span Lower Wing Ft.	Length Ft.	Height Ft.	Wing Area Sq. Ft.	Loading Lb./Sq. Ft.	Weight Empty Lb.	Weight Loaded Lb.	Useful Load Fuel, Oil & Water Lb.	Useful Load Crew Lb.	Useful Load Armament, Etc. Lb.	Speed at Water Level M.P.H.	Time of Climb to 3000 Ft.	Time of Climb to 6000 Ft.	Purpose
F.B.A.	Hull	2	1	200	Hispano-Suiza	51.2	37.9	30.0	10.0	499	7.0	2200	3520	440	350	330	87	8-0	18-0"	Patrol
D.D.	"	2	1	200	"	46.9	30.1	33.4	11.5	387	8.7	2070	3390	440	350	530	93			"
D.D.	"	2	1	200	" "	60.0	36.4	35.4	12.3	491	7.0	2440	3680	440	350	790	82	7'-0	15'-0	"
A.D.	"	3	1	200	"	60.0	36.4	35.4	12.3	538	7.0	2160	3805	440	520	680	80			"
Tellier	"	2	1	200	"	51.2	38.1	38.8	11.1	506	7.4	2425	3745	440	350	530	84	6-30"	15-30"	"
Tellier		2	1	350	Sunbeam	73.5	37.7	48.2	13.4	909	7.8	4520	7160	1160	350	1130	90	9-8"	21-0"	"
Lévy Lepen	"	3	1	280	Renault	59.7	50.0	40.7	12.4	739	7.0	3000	5180	840	520	815	93	10-0"	30-0"	"
Lévy Besson Triplane		3	1	200	Hispano-Suiza	*50.0	34.0	38.3	13.7	628	6.3	2425	3970	440	520	580	95	8-30"	22-30	
Hanriot	2 Floats	1	1	130	Clerget	27.0	23.6	23.0	9.8	198	9.2	1240	1825	220	175	190	117	3'-06	7'-30"	Pursuit
Hanriot	"	2	1	260	Salmson	36.0	36.0	26.5	10.5	301	9.5	1760	2760	310	350	340	110			"

* Span of center wing = 40.0 ft.

Fig 3 Donnet Denhaut Boat Seaplane—200 H.P. Hispano-Suiza

to have better seaworthiness. The D.D. (Donnet Denhaut) seaplane is illustrated in Fig 3. Short descriptions are given below of the Tellier, Lévy-Lepen, Lévy-Besson and Hanriot seaplanes, all of which possess special points of interest.

Tellier Seaplane

The hull of the Tellier boat seaplane (Figs 4 and 5) is copied from that used in the hydroplanes built by the firm before the war which won so many prizes at the race meetings at Monaco. It has two steps, and is divided into four water-tight compartments. The skin of the hull is formed of mahogany strips riveted together with varnished cloth inserted between, while the strength members are of ash and spruce.

The upper wing is straight, but the lower wing has a pronounced dihedral to increase the water clearance at the tips. The spars are made of steel tubing and the ribs of poplar. The wing trussing system consists of inclined struts of steel tubing incased in wood.

In the extreme bow of the hull is the gunner's cockpit, with

Fig 4. Tellier Boat Seaplane—200-Hp Hispano-Suiza

FIG 5 TELLIER BOAT SEAPLANE—200 H.P HISPANO-SUIZA

the pilot's compartment immediately behind it. The controls consist of a foot lever for the rudder and a jointed bar with a handwheel for the elevators and ailerons.

The engine is a V type 8-cyl Hispano-Suiza, developing 200 hp at 2000 r p.m. The propeller is driven through reduction gearing at 1170 r p.m The gasoline tanks behind the pilot contain 82 gal, giving a radius of action of about 400 mi. As stated in the accompanying table, the speed at water level is 84 m p.h., and the time of climb to 2000 meters (6560 ft) is 15 min. 30 sec.

A larger Tellier model was also produced during the war This is equipped with a Sunbeam "Cossack" 12-cyl engine giving 350 hp at 2000 r p m and driving a four bladed Chauviere propeller at half that speed

Other characteristics of this model in addition to those given in the table are

Chord	7 2 ft
Gap at center	7 9 ft
Dihedral upper wing	None
Dihedral lower wing	3 deg 20 min
Angle of incidence	4 deg
Area of stabilizer	40 sq ft
Area of elevators (total)	40 sq ft
Area of rudder	23 sq ft

In tests held at Saint Raphael, the French Naval Aviation Experimental Station, the Tellier Sunbeam has flown with the extraordinary useful load of 3600 lb. With the service load of 2640 lb, the machine has a speed of 80 m p h. and climbs 2000 meters (6560 ft) in 21 min The armament consists of a Lewis machine gun and two 330 lb bombs

On July 19, 1919, Marchal, the French aviator, in a Tellier-Sunbeam, crossed the Mediterranean from Saint Raphael to Bizerta in 10 hr and 29 min This is the third time that the Mediterranean has been spanned by heavier-than-air craft. The first two crossings, strangely enough, were made on land machines. It will be remembered that during the war Marchal flew across Germany and landed in Poland, where he was captured. Later, in company with Garros, he escaped to France.

Levy-Lepen Seaplane

The standard Lévy-Lepen boat seaplane (Figs. 6 and 7) has a Renault 12-cyl. V type water-cooled engine of 280 hp, driving a Chauvière propeller

As noted in the accompanying table, the upper wing overhangs the tower by almost 10 ft on each side Inclined struts are used to take this overhang instead of an elaborate system of king post trussing as is our practice Even though the Levy-Lepen is not of enormous size, it has all its control surfaces balanced—ailerons, elevators and rudder

The hull has two cockpits—one for the gunner in the bow and one for the pilot and third member of the crew farther aft, but well forward of the wings, giving good vision From the pilot's cockpit to the tail there are seven water-tight compartments, each with its inspection hole The bottom of the hull is in the form of a very flat V from the bow to the single step, which is located slightly abaft the center of gravity Aft of the step the hull sweeps up in a gentle curve to the tail—a feature of design typical of French practice.

The following particulars, in addition to those given in the table, are available

Chord	7 5 ft
Gap at center	7 4 ft
Gap at tips	7 1 ft
Dihedral of upper wing	None
Dihedral of lower wing	2 deg
Angle of incidence	2 deg 30 min
Area of stabilizer	32 sq ft
Area of elevators (total)	32 sq ft
Area of fin	8 sq ft
Area of rudder	24 sq ft

Just previous to the armistice Georges Lévy produced a new Lévy-Lepen model known as the "Alerte" This is a small two-seated boat seaplane with a remarkably high performance, comparing very favorably with the Italian Macchi hitherto considered in a class by itself.

The general design of this machine is similar to that of the larger model There are, of course, fewer interplane struts, and it has not been considered necessary to balance the controls. Attention is called to the new type of cylindrical radiator mounted on the hull behind the wings and in the propeller slip stream This radiator has become very popular, being very light, having low head resistance and high efficiency. It is used, of course, in connection with a water tank mounted in the engine group

FIG 6. LEVY-LEPEN BOAT SEAPLANE—TYPE "ALERTE"—180 HP HISPANO-SUIZA

FIG 7 LEVY-LEPEN BOAT SEAPLANE—TYPE "ALERTE"—180 H.P HISPANO-SUIZA

The characteristics of the Lévy-Lepen "Alerte" are:

Span (upper wing)	39 4 ft
Length	29.5 ft.
Useful load	1 218 lb
Motor Hispano-Suiza	180 hp
Speed (at water level)	112 m p h
Climb to 1 000 meters (3 280 ft.)	4m 70s
Climb to 2,000 meters (6,560 ft)	11m 15s.
Climb to 4 300 meters (14 100 ft.)	34m 0s

Lévy-Besson Seaplane

The Lévy Besson 200 hp Hispano-Suiza triplane boat seaplane (Figs. 8, 9 and 10) is of very original design In the first place, the center plane, incorporating the ailerons, has considerably greater span than either the top or bottom wings The arrangement is thoroughly logical, as adequate surface is obtained by a wing well above the water and yet low enough to bring the center of resistance somewhere near the center of thrust This condition is impossible of realization in a biplane boat seaplane, as the engine has in any case to be raised sufficiently for the propeller to clear the hull

As given below in the list of particulars, the angle of incidence varies in each wing and on each side of the wing

The outer struts on either side are of solid spruce, but the intermediate struts are of light steel tubing faired with spruce Incidence wires are fitted to the outer struts only, and the extensions of the center wing is by cable from top and bottom of the outer struts. The landing and flying wires are arranged according to the Spad system, crossing at the center of the intermediate struts.

The wings are made so as to fold back from the center section. With four men it takes only 3½ min. to fold the wings back and 7 min to unfold them The wings are hinged at the root of the rear spars, the front spars when the machine is rigged for flying being held by bolts passing through fittings on the center section struts To fold back the wings, all that has to be done is to unscrew the fitting on each side of the hull, holding three drift wires running to the wings and to take out the pins securing the front spars.

Ring bolts are fixed on top of the four center section struts so that the machine can be slung aboard ship.

The tail plane is raised considerably above the hull so as to be in line with the center of thrust and to have ample clearance from the water The normal angle of incidence can be

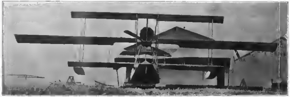

FIG 8 LEVY-BESSON BOAT SEAPLANE—200 H.P. HISPANO-SUIZA

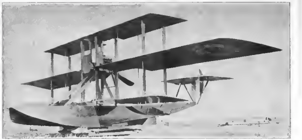

Fig 9 Levy-Besson Boat Seaplane—200 H p Hispano-Suiza

varied by an adjustment on the strut from the hull to the front spar of the tail plane. As the stabilizer is fixed to the rudder post and the latter is hinged to the stern of the hull, altering the angle of incidence throws the rudder post backward or forward as the case may be The balanced portion of the rudder is in two sections, forward of the upper one is a very small fin

There is nothing very unusual about the hull, which is built up of cedar ply, with one diagonal and one straight skin, with fabric between There are two longerons running the whole length of the bottom of the hull 8 in deep under the wings and tapering off fore and aft The deck of the cockpits is built on top of these longerons.

Fig. 10 Levy-Besson Boat Seaplane—200 H p Hispano-Suiza

Further characteristics in addition to those in the table are:

Span with folded wings	24.6 ft.
Chord, upper wing	8.6 ft.
Chord, center wing	6 0 ft.
Chord, lower wing	8 2 ft.
Gap	4.8 ft.
Angle of incidence, right upper wing	2 deg.
Angle of incidence, left upper wing	3 deg.
Angle of incidence, right center wing	4 deg
Angle of incidence, left center wing	5 deg
Angle of incidence, right lower wing	6 deg
Angle of incidence, left lower wing	7 deg
Area of stabilizer	44 sq. ft.
Area of elevators (total)	26 sq. ft.
Area of rudder	13 sq. ft.

Hanriot Seaplanes

There are two models of Hanriot seaplanes (Figs. 11, 12 and 13) similar in general design, the H.D. 2, a single seater with a 130 hp Clerget 9-cyl rotary engine, and the H D-3, a two-seater with a Salmson 260 hp 9-cyl. radial engine. Both

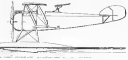

Fig. 11. Hanriot HD-3—Side Elevation

seaplanes are modifications of the well-known airplanes of this make They are well adapted for pursuit work, having a good turn of speed and excellent climb Unfortunately, the endurance is very limited, being little over two hours.

The fuselage is built up with four longerons in the conventional manner, but is faired out to a circular section forward to take the motor The top is also faired

The wing truss system is of the so-called "one and a half strut" type, consisting of a pair of interplane struts on each side of the fuselage and two additional pairs of inclined struts from the top longerons of the fuselage to the upper wing Both models have a very pronounced stagger and a slight dihedral.

The larger machine has ailerons on both upper and lower wing The ailerons, elevators and rudders are all balanced In the single-seater, however, the controls are unbalanced and

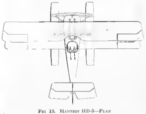

Fig 13. Hanriot HD-3—Plan

ailerons are provided on the top wing only. Both models have a fin forward of the rudder.

The floats, which are very well designed examples of the single-step variety, are attached to the fuselage by an M type alighting gear. Further bracing is afforded by wires running from the floats to the bases of the outboard struts.

The single-seater carries two Vickers machine guns firing through the propeller, while the larger model, in addition to the armament for the pilot, has two Lewis guns on a Scarff type ring mount for the gunner. It will be agreed that the

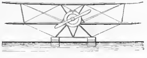

Fig. 12 Hanriot HD-3—Front Elevation

H.D-3 could have given even the redoubtable German Brandenburg monoplane seaplane a good fight

Certain characteristics of the Hanriot seaplanes, in addition to those given in tabular form elsewhere, are as follows:

	H. D.-2	H. D.-3
Chord, upper wing	4 1 ft	4 6 ft
Chord, lower wing	3.5 ft.	8 0 ft.
Gap at center	3.8 ft.	4.8 ft.
Gap at tips	4 0 ft	5 1 ft
Stagger	2.1 ft.	2 0 ft
Dihedral, upper wing	4 deg	2 deg
Dihedral lower wing	None	None
Angle of incidence	2 deg.	2 deg
Area of stabilizer	18 4 sq ft.	18 8 sq. ft.
Area of elevators (total)	12 8 sq ft.	16 7 sq ft
Area of fin	2 0 sq ft.	2 2 sq ft
Area of rudder	7.9 sq ft.	8 8 sq. ft.

Notes on Glue Problems

The object of a new glue study is the reduction of cost of water-resistant glues by the addition of cheap inert materials or certain chemicals.

Samples of vegetable proteins are being collected for a study of their glue-making properties.

Experiments have shown that animal glues are weakened by long heating

According to the results of strength tests, a thick layer of animal glue in a joint is stronger than a thin layer Whether or not joints of other kinds of glue vary in strength with varying thicknesses has not been determined.

It is evident from completed tests that all glues dull woodworking tools more than solid wood does, and that casein glues do more damage to cutting edges than animal or vegetable glues Jointer blades are apparently injured to a greater extent than rotary saws in passing equal distances through glued joints.—*Forest Products Laboratory.*

Electrical Timing Apparatus for Speed Tests

At Martlesham, England, the British R A. F experimental station, the above apparatus is in systematic use. It consists essentially of a tape machine and two recording lens operated by electro-magnets. Time is recorded by an electro-magnet connected to a second pendulum. With observers of average efficiency the timing of a flight can be found correct to the nearest one-twentieth of a second

The Supply of Meteorological Information*

By Lieut.-Col. H. G. Lyons

The difficulties and risks of aviation are so greatly increased by unfavorable atmospheric conditions that the aviator is naturally strongly impressed by the importance to him of the best and fullest meteorological information that he can obtain, and he may be led to assume that the information that he requires must necessarily suffice for all other activities and all lines of investigations.

The truth is rather that the fullest meteorological information of all kinds is needed, so that it may be studied and worked upon by trained meteorologists in order that we may learn more of the principles underlying the phenomena that we observe, and from this standpoint be better fitted to advise aviators as well as all others to whom weather and climate are factors with which they have to be reckoned.

Though aviation makes probably larger demands on that part of meteorology which deals especially with weather, that is, with the short period changes of meteorological conditions, it does not thereby cover the whole field of meteorology any more than the chemistry required in the work of any branch of chemical industry necessarily covers the whole field of chemical science. The same phenomena which are of importance in aviation are among those which the meteorologist studies for the progress of his science. The interest and the importance of the force and direction of the wind at various altitudes above the surface of the earth, which are observed by means of pilot balloons, shell-bursts and other methods, are not limited to the aviator alone. The forecaster needs them in his work, in gunnery they are carefully observed and utilized, the meteorologist in his study of the physical conditions of the atmosphere requires these as data from a region where friction with the earth's surface, and heating and cooling of the air by convection, do not complicate the problems with which he has to deal. It is indeed impossible to say that any particular meteorological study is unnecessary or useless for aviation, for gunnery, or for any specific application of meteorological science. Measurements of wind, temperature, humidity at various altitudes, taken with all the precision that can be attained are indispensable to the meteorologist who is seeking the principles which underlie the phenomena that we observe, and which, when determined, represent a definite advance in our knowledge and thereby in our powers of practical application. Observations made in one line of investigation will often, in practised hands, lead to advances in knowledge which are of the utmost importance in their application in quite different fields. Thus the observations which Major G. I. Taylor, F.R.S., made in 1912 on board s.s. "Scotia," which was chartered for studying the distribution of drift ice in the North Atlantic, have led him to most important advances in our knowledge of eddy motion in the atmosphere, which has thrown light on the conditions which determine the formation of mist, fog and low cloud, thus materially advancing our knowledge of a part of one subject which is of supreme importance to the aviator.

Thus all the meteorological information which is collected for any purpose should be made accessible to all workers since the same material will be utilized for many different purposes. Publication in the forms which have been adopted after careful consideration as being the most suitable is one way, but there will also be a mass of original records, special investigations and other researches to which the working meteorologist should have access and to which he should be guided by an effective system of registration and indexing. The material is so vast and so varied that it soon becomes unmanageable unless an effective means exists of tracing readily the different parts of it.

In the Meteorological Office there are records extending over more than half a century, and besides these there are hundreds of investigations which have been made from one time to another for various purposes. In the present conditions of a wider utilization of such information a more complete and more detailed means of leading the inquirer to those pieces of information which bear most directly on the object of his search is being introduced. But to render this really effective it must include not only the material that is stored in a single institution, but it must also indicate where any additional information may be found elsewhere.

Next to the importance of realizing that all meteorological information must be available for use in all branches of study, and all kinds of application, is the need for general co-operation on the widest lines in all parts of the subject. The position of any particular station on the earth's surface, whether in the polar, temperate, or tropical regions, its situation on the coast, in the interior of a continent, or an oceanic island,

Testing for Direction and Velocity of Wind

near sea level, or on a mountain range, all these and many other factors impress their influence on the phenomena which are observed at it. Before we can utilize such information, therefore, we must know all about the station from which it comes, and in order to disentangle from the results obtained the effects of the various factors, we must know precisely how the observations have been taken and what their accuracy may be.

This is ordinarily attained by taking such observations at certain hours, by certain methods, and with specified types of instruments, so that the results of one station shall be, so far as possible, comparable with those of another. Absolute uniformity of practice may not be everywhere attainable, but ever since international co-operation in the study of meteorology has been practised the greatest measure of uniformity has been the constant aim of the meteorologists of all countries. It has been recognised generally that for any service to adopt different hours of observation or different methods of observing would be to increase the difficulty of utilizing the results in conjunction with those of others and thereby to diminish the return for the expense incurred in their collection. Such organized co-operation is the more necessary since the meteorologist is always in the position of an intelligence officer, for he depends almost wholly on the information which he can procure and collect from far and wide for his material. He seldom utilizes his own observations alone, but is usually dependent on those which have been taken by other workers, probably in other lands and under very different conditions. The phenomena with which he deals, even those which are rapidly changing, cover very large areas, for cyclonic depressions are often more than one thousand miles across, and they may move at a rate of 30 to 40 m. p. h. There must therefore be the fullest co-operation between observers of all countries and the greatest uniformity of practice in observations, in instrumental equipment, and in methods of summarizing and transmitting information, if the best results are to be obtained.

All meteorologists have long recognized that the weather of any particular region is only the local result of causes

Chart Showing Weather Bureau Method of Showing Wind Direction at Different Altitudes

which belong to the general circulation of the atmosphere, so that a collection of the meteorological data of the globe was a first necessity.

This is being provided in such a form as can be produced at present by the publication of the Meteorological Office, the "Réseau Mondial," which gives the pressure temperature and rainfall for each month at a number of selected stations, two for each ten-degree square being taken wherever possible. This publication, of which three years, 1911, 1912, 1913, have appeared, is only possible because of the uniformity and co-operation which has been achieved by international effort.

Changes in these international arrangements will no doubt be necessary from time to time, but all experience shows they should not be made hastily. Moreover, a consensus of favorable international opinion is difficult to obtain since social and administrative conditions in various countries differ so as to make readjustment difficult. As usual some compromise is usually inevitable, but the main principle of increasing wherever practicable the uniformity of practice already attained must be kept in the foreground.

The next point for consideration in the supply of meteorological information is that for one special class of that information rapidity of transmission is of the highest importance.

That division of meteorology which deals with weather is primarily concerned, at least in extra-tropical regions, with the changes which take place from hour to hour and from day to day, and these changes take place often with great rapidity and spread quickly over large areas, so that if they are to be anticipated and warnings issued of such coming changes as little time as possible should be expended in the collection of reports and the issue of forecasts and warnings.

In this country forecasts have long been prepared three daily, from observations at 7 a. m., 1 p. m. and 6 p. m., but with the increase of aviation during the war and the necessity for the issue of forecasts of the weather at an hour before the day's plans for operations were under consideration, an additional forecast and report based on observations at 1 a. m. was introduced, and has been continued up to the present time.

For years past the meteorological services of most European countries, as well as those of India, Canada, the United States, Egypt, Japan, and some others, have issued daily weather reports and maps of their area and of the surrounding regions, interchanging information by telegraph under international agreement. Europe was in this way fairly well provided with information of current weather from a large network of stations, to which were added in 1909 reports from ships of the trans-Atlantic steamship lines.

Under present conditions these international services can be and have been for the most part resumed, but the new demands for a quicker and more frequent supply of information are much larger and more numerous than those of five and six years ago. The forecaster must now receive his reports within an interval of not more than an hour after the observations have been taken, and for them to be utilized to the full, his deductions from them should be available half an hour later.

This means that a large amount of information has to be transmitted at fixed hours four times daily, and as all observations are, so far as can be arranged, synchronous for the purpose of being directly comparable, all neighboring countries are occupied in the receipt, dispatch and and interchange of reports at the same time. Wireless telegraphy is going to assist greatly in the transmission, but it has other and numerous calls upon it, and the necessity for meteorological reports being transmitted at definitely fixed hours makes international co-operation and uniformity of practice all the more essential. Again, the margin of time available for decoding reports, plotting the information on a map, considering the meteorological conditions therein represented, and deducing the probable changes and developments, is very small, and every cause of delay must be avoided if the necessary promptitude is to be attained. Services which employ special scales for reporting observations or special methods of coding, recipients who demand reports in special form, all these and other deviations from a fixed procedure cause loss of time when every minute is of importance, and as far as possible such complications should be avoided.

Local conditions may greatly influence the weather which is experienced and these cannot well be taken into account in the forecast issued by a central institution. To do so would make the forecast message too long, and would necessitate a very large number of special forecasts being drafted for which there is no time. Such local characteristics are best allowed for by the local meteorological officer, who receives from the central institute a forecast of the general conditions, and so much of the observational material of the reporting stations as he may require. With this he can edit, amend, and amplify the general forecast, so that it becomes a special forecast for his own particular area, taking account of its peculiarities, and in this his local knowledge should materially aid him.

But whether it is a forecast issued from a central office or from a local secondary forecasting station, some technicalities can hardly be avoided; the prevailing or anticipated conditions must be described in a few lines at most, and if precision as well as brevity is to be attained, technical terms cannot be avoided.

The daily weather report which was issued before the war from the Meteorological Office, was a document which had grown up gradually and by successive changes. It had been the rule to publish with the map the statistical material which had been used in its production, so that the reader could check its correctness, and, if he pleased, draw his own deductions from it.

But under service conditions something simpler, plainer, and more direct in its presentation of the opinions of the trained meteorologists who prepared it, was needed. Those who had to make use of the daily weather reports were usually far too busy to wish to study the statistical material before accepting the meteorological opinions which were

*Excerpt from a paper read before the Royal Aeronautical Society of Great Britain

offered to them. They wanted a direct statement of expert opinion of which they could make use in preparing their own plans of action. The desire for such expert assistance was also shown by many requests that forecasts should be expressed in "perfectly simple and non technical language." To this very reasonable request it was not so easy to accede as it may seem. Such expressions as "a depression advancing from the westward," "a secondary depression developing over the Channel," "an anti-cyclone spreading northward," are more than mere statements of fact; they convey to all who are acquainted with meteorology much additional information depending on the weather conditions described, which it would take several paragraphs to describe simply and in non-technical language. The same is true of every technical subject, whether it be a branch of science, or technology, or for that matter of any form of human activity. Everywhere technical terms come into use, since they are convenient and economical, and they describe a certain set of conditions more precisely than can be done by any circumlocution. But to meet these requirements as far as possible, a special set of weather reports was issued in the early morning, at noon, and in the afternoon, to all who required them, and from these statistical data were omitted.

Now that hostilities have ceased, the opportunity has been taken to revise the daily weather reports in order to make them more useful and more convenient for reference. The simplified morning report of war days has been transformed into a British daily weather report, in which all the information from the United Kingdom is included, and is issued before noon. Later in the day an International daily weather report is issued, in which all the data from foreign countries appear. In addition, a special two-page supplement, containing all upper air observations from the observatories of the Meteorological Office and meteorological stations of the Air Ministry as well as from some in France, is published daily at noon.

These cannot, of course, replace the telegraphed reports and forecasts for recipients out of London, but they provide the material for reference and future study. Under the present conditions of world-wide flying, it is not the weather service of this country alone that is of importance. A large part of the world is dealt with more or less completely by the different meteorological services, though the density of the networks of stations naturally varies widely. However, there are already large areas over which the weather conditions are reported and studied daily in greater or less detail, and this study will certainly increase under the new demands that are being made upon it.

In some regions the problems are less complicated than in others, for as we approach the Tropics for example, weather conditions usually become less disturbed, and at certain seasons, at any rate, day follows day with but slight difference, and important disturbances are rare. In the Mediterranean, from May or June to the end of September, settled weather is the rule over the Eastern half at least, and North Eastern Africa presents very stable conditions, except occasionally in the northern part during the winter months, and also south of latitude 15°N. in the summer, when the Monsoon rains spread northwards over the Sudan. India can show similar cases.

Now the meteorological services of all regions will have, in addition to the study of their own area, to assist in the provision of information for such air routes as pass them, and, in co-operation with the other services in the Empire, investigate those meteorological problems which are continuously arising, and especially those which the introduction of aviation on a large scale has now made more urgent.

These services already issue their daily weather reports, but probably they too will find that some modification of them is necessary to meet these new demands and enlarged requirements.

Whenever forecasts have to be prepared, reports from many stations must be collected and a weather map drawn, and if drawn it should be issued to all whom it can reach in time. Thus on every war front, daily weather maps have been regularly issued, often several times daily, and at this moment one is furnished to the British Force in North Russia, and in all future operations the same will be required.

This intimate co-operation between the different meteorological services which aviation necessitates increases the importance of imperial and international consultation in order that information may be provided on all routes and at all stations as nearly as practicable in a common form and with the least possible delay.

The foregoing remarks relate particularly to that branch of applied meteorology which may be termed the weather service: the reports on current weather conditions and the estimates which are formed of the changes which will take place in them and the times at which they will occur. These, we have seen, may usually be amplified and improved for any particular station by a meteorologist who is acquainted with local conditions and has determined how they react upon different types of weather.

This is the class of meteorological information which appeals most directly to the aviator and is of the greatest importance to him.

But besides reports on the current weather there exists also the great mass of information which has been accumulated during many years by all meteorological services and observatories, which is made up of daily observations taken at two, three or more fixed hours and which has for its object the provision of material for the solution of the problems of meteorology and the general advancement of the science.

From this the general meteorological character of a station or a region may be determined, as well as the changes which takes place from month to month. Essentially it is the long period phenomena which are considered; rapidity of transmission is not of the same importance as it is in a weather service; mean values of temperature, rainfall, etc., are obtained, the extreme values observed are noted, and generally it is climate rather than weather which is studied.

Aviation has a number of questions to which this material can supply the answer, but much of it has to be rearranged to put it in the most suitable form required by new demands. The frequency with which a certain temperature is attained, the number of days on which the wind blows from a given direction with a certain force, the number of days on which fog or mist occur and the hours at which they are most prevalent—all this and much more information is generally obtainable from these records, but it has usually to be extracted and compiled specially. No one form of record will suit all the inquiries that may arise, and the information must always be worked up to meet special requirements.

Seeing how voluminous the material is, this is no light task, and, moreover, it demands skilled direction if the best use is to be made of the data which are to hand. All published material is not of the same value, and manuscript unpublished material may contain errors or require correction before it is utilized, which may be overlooked by anyone who is utilizing it mechanically.

Now that meteorological records are being more largely worked upon and will continue to be worked upon in the future, it is of the highest importance that there should be at a central institute as complete a collection of them as possible. Also that at that institute a highly efficient system of registration and indexing should be in operation, so that inquirers and students may be referred readily to all sources of information, whether published matter, manuscript records or investigations that have been carried out and then filed away. The last group is not the least important, for work of this kind may be needlessly repeated unless there is a ready reference to what has already been done.

There is a large amount of information of such a statistical character published in this country already, weekly and monthly weather reports of the United Kingdom appear regularly, but for the war the climatological atlas of the United Kingdom would have been published by the co-operation of the Meteorological Office and the Royal Meteorological Society. Pilot charts of the North Atlantic and the Indian Ocean appear monthly and contain much information relating to these ocean areas which have been collated from the valuable meteorological logs contributed by ships' officers.

No doubt, in view of the new demands made upon meteorology, some of these forms of supply need revision to make them more widely useful; average conditions can be set out in publications appearing at moderately long intervals, while current information must be distributed quickly and in a less cumbersome form. Inquiries are already being received with increasing frequency, but provision is being made to deal with them on a larger scale and to encourage them.

Estimating Performance of an Airplane

Given Engine, Flight Duration and Military or Commercial Load

By Lt. Col. V. E. Clark, Air Service, U. S. A.

In a previous article on this subject* the writer showed a series of curves intended to serve as a means for quickly obtaining rough estimates of the ceiling, and high and low speeds and climb at all working altitudes, of an airplane having given total weight, surface area, engine power and general arrangement.

Now it appears possible to estimate roughly the total weight of an airplane having given engine, required flight duration and military or commercial load. It is also possible to estimate its surface area having given these three things and the general arrangement and surface loading factor.

Thus, it appears that, before starting the design of an airplane, the engineer can, by linking the following data with the preceding set of curves referred to, roughly and very quickly predict the performances at all altitudes of the proposed airplane—starting with values of the weight, power and rate of fuel consumption, of the engine which it is proposed to use, the required flight duration, and the military or commercial load to be carried. It is also necessary to decide the required landing speed, which gives a value for the surface loading.

With these same data, we can, having given the proposed flight duration and military or commercial load, choose the most suitable engine to use to obtain given required performance. Again, having given required performance, proposed engine, and military or commercial load, we can estimate the possible flight duration and radius of action, or, having given engine, required performances and radius of action, we can estimate the possible or most economical military or commercial load, etc.

For the data in Table V, it is assumed that varying with types and sizes as indicated, the weight of the fuselage bears a certain relation to the weight of the items which it contains, that the weight of the landing gear bears a certain relation to the weight of the airplane it supports on landing; that the weight of the main planes bears a certain relation (varying with surface loading value) to the total weight they support in flight, and that the weight of the tail surfaces bears a certain relation to the weight of the main planes which they stabilize and control. The main planes on biplanes of 150 sq. ft. area may weigh as low as 0.8 lb. per sq. feet—on biplanes of 1,500 sq. ft., as high as 1.55 lb. per sq. ft. Monoplanes are heavier per unit area, triplanes are lighter.

Therefore, the completely loaded airplane has been divided into seven components as indicated hereinafter, values for three of which are to be assumed—enumerated in the second paragraph of this article.

The weight of the fuel and oil varies with the power of the engine, its fuel efficiency, and directly with the duration of the flight. For the ratio between fuel capacity and flight duration, it is assumed in this article that the engine is driven at full throttle during the entire flight. The pilot can by throttling, fly at a more economical speed (greater distance per gallon), and, with a given fuel capacity, cover more distance, and stay in the air much longer, without great loss of speed, especially if a propeller of very high pitch is used. Engineers may make the necessary correction for this and still use the method shown.

Fig. 17 indicates the rate at which fuel consumption varies with altitude, it having been assumed that the engine is driven so as to develop power as indicated in the power-altitude curve in Fig. 1 (preceding article). By using this curve we can, having given rate of fuel consumption at sea level, estimate the duration of flight at any working altitude.

Readers must realize that the results obtained by using the method shown will be very approximate only. The values for the various coefficients shown in Table V indicate how greatly these vary with difference in type and size of airplane. For instance, in a machine which has a long fuselage (in proportion to the span) the weight of the fuselage will be high, but the weight of the tail surfaces will be low. Wings with high aspect ratio and high gap-chord ratio and long bays, while more efficient aerodynamically, will weigh more than wings of the same area of low ratios. Other things being equal, the higher the structural factors of safety the greater the weight. Again, careful and ingenious design will

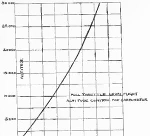

Fig 17

eliminate weight without sacrificing strength. If high speed is more to be desired than high ceiling and good climb, the designer may, in order to increase aerodynamic efficiency at low angles of incidence, be forced to add weight, or, vice versa, if climb and ceiling are more important, he may reduce weight at the cost of aerodynamic efficiency.

Method.—The seven components of the airplane, ready for flight, are as follows:—

Let

P = weight of engine, complete with radiator, shutter and connections, all water, propeller, exhaust manifolds, carburetor, ignition systems, starter, etc., but not including mounting tanks or connections.

F = weight of fuel and oil, not including tanks or connections. To obtain a value for F, we must, after deciding duration of flight, know the rates of fuel and oil consumption of our engine and refer to Fig. 17, after deciding desired altitude for cruising. Corrections may be made if it is proposed to fly with engine throttled.

U = weight of useful military or commercial load, including pilot and passengers, armament, ammunition, bombs, radio sets, camera, etc. . . . or mail, express, spare parts, etc.

The items P, F and U may be called the three known variables.

Then, let

B = total weight of fuselage or fuselages and nacelles, including not only structure, covering, cowling, tail skid, etc., but everything contained within, such as engine mounting, tanks, seats, etc. . . ., but not including any

* See Sept. 15, 1919, issue of AVIATION AND AERONAUTICAL ENGINEERING.

item listed after P, F or U (Tanks usually weigh about 1 lb per gal capacity)

W=weight of main planes including doped fabric, ailerons, tip skids or floats, interplane struts, wiring and fittings. Let A=net area of main planes, including flaps

E—weight of all tail surfaces, complete, including external bracing and control wires.

G=weight of landing gear, complete

I Then T, total weight of airplane, completely loaded, ready for flight=P+F+U+B+W+E+G.

Surface Loading —

II $L = T/A$

The value of L which it is decided to use will depend upon the desired landing speed and proposed wing section and arrangement

Using coefficients, varying with types and sizes, as indicated in Table V.

III. $B = C_1 (P+F+U)$; $C_1 = \frac{B}{P+F+U}$

IV $W = C_2 A = \frac{C_2 T}{L}$, $C_2 = \frac{LW}{T}$

V $E = C_3 W = C_3 (C_2 T/L)$, $C_3 = E/W = \frac{EL}{C_2 T}$

VI $G = C_4 T$, $C_4 = G/T$

Then

VII $T = \frac{(1+C_1)(P+F+U)}{1 - \frac{C_2}{L}(1+C_3) + C_4}$

It is suggested that engineers, if they consider the method useful, expand Table V as data may be obtained on further types

The method is to first decide on the engine to be used, the desired flight duration, and the military or commercial load to be carried. Then decide upon the wing loading L. Then decide upon the general arrangement or type and enter Table V, choosing the type thereon most closely resembling the proposed machine, to determine the coefficients C_1, C_2, C_3 and C_4.

We now have values by which, from formula VII, we obtain the approximate total weight of the proposed airplane.

From formula II, having already decided the proper value for L, we obtain our value for A, the area of the main planes, and we can quickly estimate the spread, chord and gap of the main planes, and the proper areas and moment arms for the tail surfaces

From this, we can make a preliminary layout drawing of the conventional three views

In the meantime, another man can—having obtained the value of T, the total weight, and knowing the power of the engine and the surface loading L—enter the charts 2 to 16 inclusive (see preceding article) and estimate the ceiling, and climb and high and low speeds at all working altitudes. Then a chart similar to Fig 16 may be shown on the same sheet with the three view drawings

EXAMPLE

Suppose it is proposed to lay out a machine similar in general arrangement to the DeH-9 or USD-9A

TABLE V

Type	T	A	L	P	F	U	C_1	C_2	C_3	C_4
Ord. 1-seater training	1103	180	6.13	298	139	173	.350	.833	.152	.070
Std E 1	1180	153	7.81	298	144	185	.434	1.048	.207	.062
Thom M 1	1275	240	5.32	298	166	185	.400	.825	.243	.060
Nieuport 17	1287	164	7.85	262	178	230	.347	.908	.146	.051
Vought VE 7	1928	293	6.06	685	185	370	.220	.960	.138	.045
Curtiss JN 4D	1953	358	5.45	518	164	366	.327	1.130	.140	.046
Thom. M MB 3	2078	250	8.27	795	374	348	.134	.990	.174	.031
SE 5 Amer. bt	2100	246	8.87	725	248	305	.348	1.008	.187	.043
Pomilio VL-8	2106	280	7.63	880	320	368	.187	.857	.144	.039
Ord 1-seat pursuit	4358	281	9.02	870	406	762	.178	1.170	.127	.067
Loening Monoplane	2570	235	10.8	837	387	806	.184	1.262	.152	.043
Verville CF 1	2600	208	8.68	851	365	350	.010	1.418	.108	.035
Lepere C 11	3712	415.5	8.94	1118	810	825	.201	1.300	.120	.048
DeH-4	3903	450	8.60	1100	676	784	.281	1.100	.122	.034
USD-9A Rec	4322	489	8.84	1215	937	665	.229	1.284	.132	.034
Pomilio VL-12	4486	578	7.76	1140	900	1100	.233	1.170	.101	.039
USD 9A Bmbr	4878	488	9.98	1126	933	1324	.272	1.250	.109	.030
A E G	7760	800	9.63	2248	1200	1784	.219	1.195	.139	.041
O-11	8300	870	9.54	2487	1818	1278	.167	1.722	.060	.026
Martin Bomber	9590	1070		2400	2000	1825	.237	1.365	.110	.061
Handley Page	14780	1366	6.90	3650	2450	3503	.258	1.535	.078	.042
HS-1L	5000	603	8.08	1122	730	1102	.582	1.474	.178	
NC 1	23000	2380	9.66	4000	6020	1780	.340	1.024	.227	.100

l—The total weight of the useful load which it is desired to carry is, let us say—685 lb

P.—We decide to try the Liberty 400 hp, 12-cyl, direct drive engine, with a nose radiator and a small auxiliary radiator

Then P=weight of engine + propeller (45) + hub, bolts, nuts (25) + radiators, shutter, etc (153) + water (125) + exhaust manifolds (23)=1215 lb

F—We decide to have fuel capacity sufficient for 5.5 hr. flight at full throttle at 10,000 ft altitude. The rate of consumption of fuel of this engine is .509 lb per hr at sea level, and of oil—.0373 lb hp hr. Consulting Fig 17, we see that the probable hourly consumption of fuel and oil at 10,000 ft = 400 × .5463 × .763 = 166.6 lb. Then F = 5.5 × 166.6 = 917 lb, of which 854 lb (139 gal) is gasoline. Should the pilot fly at throttle for three-quarters power, he can remain in the air, at 10,000 ft for 917 ÷ (¾ × 400 × .5463 × .763) = 7.34 hr

We decide upon wing loading, L = 8.84 lb./sq ft.

Referring to Table V we estimate that

$C_1 = .229$
$C_2 = 1.284$
$C_3 = .132$
$C_4 = .034$

From Formula VII —

$$T = \frac{(1+C_1)(P+F+U)}{1 - \frac{C_2}{L}(1+C_3) + C_4}$$

$$= \frac{(1+.229)(1215+917+685)}{1 - \left[\frac{1.284}{8.84}(1+.132) + .034\right]}$$

=4,322 lb —estimated total weight loaded

Area main planes $= \frac{4{,}322}{8.84} = 490$ sq. ft.

Referring to the preceding article, to the first example, charts Figs. 2 to 15 (inclusive, and tables I and II, we get performance chart Fig 16

The high speed at 10,000 ft is 124 m.p.h. Therefore the radius of action at full power of our proposed airplane, carrying 685 lb of useful load, is approximately 5.5 × 124 =682 miles

The Influence of Water Injection on Engine Performance

A short investigation has been conducted at the Bureau of Standards to determine the effect of water injected into the intake manifold of an internal combustion engine. This investigation was carried out on two different engines, truck and automobile, but the results in general are such as to apply to airplane engines.

The first series of tests was conducted to determine whether the use of water injected into the intake manifold had any effect on the horsepower output and fuel economy; the second series to determine the effect upon the carbon deposit on the cylinder walls and piston heads.

The data obtained indicate that in an engine of good design there is no appreciable gain in power or fuel economy due to the injection of water, but in a badly carbonized or a poorly designed engine, where hot spots due to improper cooling are present, a slight increase in power may result. If enough water be used, it will remove a small portion of the carbon but will cause at the same time a considerable reduction in the operating efficiency of the engine.

The maximum amount of water used in these tests was limited to that which did not materially interfere with the normal operation of the power output of the engine and the results do not indicate the value of much larger quantities of water as injected under special conditions solely as a carbon removing agent.—*National Advisory Report.*

Note on the Efficiency of Tandem Propellers

By J. G. Coffin

Assistant Director of Research, Curtiss Engineering Corp.

It is sometimes a question whether it is better to install two engines in one nacelle, thus diminishing head resistance and, in consequence, having one propeller, a tractor, and the other a pusher, or to install each engine in a separate nacelle and take a loss in added head resistance.

This decision is, of course, determined by the structural difficulties involved, as well as by the horsepower of the available engines, diameter of the single propeller necessary to take care of large horsepowers, increase in moment of inertia of the machine as a whole, and by other considerations. In order to decide the question to the best advantage, it is well to be clear on the fundamental principles involved, and the following discussion may be of interest and value in coming to a decision in any specific case.

The result shows that there is bound to result a decrease in the overall propeller efficiency of a tandem arrangement as compared to propellers in parallel. Whether this impaired efficiency is more than compensated by other attendant advantages or not is a matter of calculation in any specific case, and each case must be treated on its merits.

Consider, for example, that two propellers are attached to a machine flying at 100 m.p.h., and assume a slip of 20 per cent in the forward propeller. This means that air entering the propeller at 100 m.p.h. issues at 120 m.p.h. The rear propeller then receives its air at 120 m.p.h.

At first glance it would seem that if the rear propeller were properly designed for this higher air speed there would not be any impairment in its efficiency. This special design must, of course, be carried out, but we shall show below that even then there is a loss in efficiency.

Assume that the fore propeller has an efficiency of 80 per cent for its working condition and also that the rear propeller has an equal efficiency for its working condition in the wake of the one in front of it. Let T_1 and T_2 be the thrusts of the fore and aft propellers respectively, and P the horsepower of the engines, then we have by definition

$$\frac{T_1 \times 100}{375} = \frac{80}{100} P \qquad (1)$$

Also

$$\frac{T_2 \times 120}{375} = \frac{80}{100} P \qquad (2)$$

By division we obtain

$$\frac{T_1 \times 100}{T_2 \times 120} = 1 \qquad (3)$$

or

$$T_2 = \frac{10}{12} T_1 \qquad (4)$$

Now the useful delivered power of the fore propeller is

$$\frac{T_1 \times 100}{375} \qquad (5)$$

and the *apparent* useful power of the rear one is

$$\frac{T_2 \times 120}{375} \qquad (6)$$

But actually the *effective* useful power of the rear propeller is not that given by the preceding equation, but is

$$\frac{T_2 \times 100}{375} \qquad (7)$$

Dividing (7) by (5) we get for the ratio of their effective delivered powers

$$\frac{\text{effective delivered power rear prop}}{\text{effective delivered power fore prop}} = \frac{T_2}{T_1}$$

and by (4)

$$\frac{T_2}{T_1} = \frac{10}{12} = 83.4 \text{ per cent}$$

Hence the effective efficiency of the rear propeller, although correctly designed for an efficiency of 80 per cent, is only 83.4 per cent of 80 per cent, or 66.7 per cent. This is a reduction of 13.3 per cent in its assumed efficiency. The combined efficiency of the two is therefore only

$$\frac{80 + 66.7}{2} = 73.7 \text{ per cent}$$

a decrease of 6.3 per cent on the total horsepower involved. This argument applies, of course, in a similar manner to any other actual case.

The above numerical example may be generalized as follows where

T_1 and T_2 are the propeller thrusts of fore and aft propellers respectively

μ_1 and μ_2 their *designed* efficiencies

μ_2' the *effective* efficiency of the rear prop

V the air speed of the machine.

$V + S_1$ the slip stream speed due to fore propeller

P_1 and P_2 the brake horsepower of the engines respectively

Then

$$T_1 V = \mu_1 P_1$$
$$T_2 (V + S_1) = \mu_2 P_2$$
$$T_2 V = \mu_2' P_2$$

Hence

$$\mu_2' = \frac{T_2 V}{P_2} = \frac{T_2 V \mu_2}{T_2 (V + S_1)} = \mu_2 \frac{V}{V + S_1} = \mu_2 \frac{1}{1 + a}$$

where a is the slip stream ratio

From experiments made in England it appears that instead of S_1, 6/10 of its computed value should be used. This will improve the computed efficiency of the rear propeller somewhat

If $a = \frac{1}{5}$ (corresponding to 20 per cent slip)

Using a slip ratio of 6/10 of ⅕ we get

$$\mu_2' = \mu_2 \frac{1}{1 + \frac{6}{10} \times \frac{1}{5}} = 89.4 \text{ per cent } \mu_2$$

The figure actually given for the efficiency of the rear propellers was 93 per cent of its computed efficiency.

The net result of the argument is that it is always detrimental to run a propeller in the slip stream of another unless other attendant gains more than compensate for the necessary loss in efficiency thereby incurred

It is also evident that as any increase in slip will reduce the rear propeller efficiency, climbing and slow speed are bad conditions for propellers in tandem

Hydrogen Impurities on Airship Fabrics*

By Lt Comdr P L. Teed, R N V.R

The presence of arsine (AsH_3) and phosphine (PH_3) in hydrogen has been found to have a damaging action on airship fabric, for instance, a balloon which burst at Milan in 1906 was found to have weak patches in the fabric, which patches contained arsenious and phosphoric acids. Arsine and phosphine in hydrogen (pure) do not appear to have a damaging action on fabric

The oxidation products of these gases do the damage. In an ordinary airship envelope there is found besides the hydrogen, water vapor, nitrogen, oxygen, traces of arsine and phosphine (particularly if the gas has been made by the silicol process)

Under the conditions cited the arsine and phosphine oxidize if copper fastenings are used inside the gas bag. The same reaction takes place if the internal rigging has been treated with copper compounds, the resulting acid liquid falling on the fabric and very greatly reducing its strength. Three Astra ships have had their curtains burst in the air (1916-17), and this has been attributed to the secondary effect of phosphine.

The existing rules are: *No copper fastenings. No copper compound treated rigging or fabric.* If metal fastenings are to be used, as far as is known *aluminum* can be used with safety.

* Aircraft Technical Note, Bureau of Construction and Repair, Navy Department.

Inadequacy of Visual Inspection in Kiln-Drying

By H. D. Tiemann, M.E., M.F.

Physicist and Dry Kiln Specialist, U. S Forest Products Laboratory

Brashness, internal stresses, and hidden checks produced by poor drying may be passed undiscovered in the most rigid inspection, since they cannot always be determined by direct examination of the material The drying process itself is, therefore, of prime importance, not only for the saving of material through the avoidance of due waste from injuries in drying but even more so for the assurance that the material which passes inspection shall be free from subtle defect or possible weakness. For this reason it has become necessary to draw up very careful specifications for the drying operations themselves, and to place inspectors at the kilns to see that the operations are conducted in accordance with the specifications The need for this was realized when the airplane program was undertaken at the beginning of the war, and the Forest

Fig 1 Dry Kilns Built by the Signal Corps at Vancouver, Wash.

Products Laboratory of the U. S. Forest Service, Madison, Wisconsin, was looked to for the necessary information

The Forest Service had for many years conducted exhaustive experiments on the mechanical properties of various species. On the effect of various treatments and temperatures upon their properties, and develop methods of kiln-drying woods from the green condition.

The Signal Corps specifications* were prepared on the basis of this previous knowledge of drying and of the mechanical properties of woods. The results of a few preliminary tests made in April and May, 1917, upon some airplane material of partly air-dried spruce and ash were also taken into account

Necessity for More Exact Knowledge as to Strength

It was evidently desirable, however, to establish definitely and beyond all question what effect would be produced upon the strength of the wood by methods of drying given in the specifications, and to obtain more exact knowledge about the limiting conditions for each species of wood as regards the severity of treatment beyond which it would be unsafe to go. This called for exhaustive drying and strength tests, which were at once undertaken at the Forest Products Laboratory. Shipment of logs of various species were received at the Laboratory The logs were sawn, and materials selected therefrom were kiln-dried under different sets of conditions. Mechanical tests were then conducted to compare this material with matched green specimens, and also with matched specimens that had been set aside to air-dry under most favorable conditions. This requires the lapse of considerable time before the final analysis can be made, in order that the material may be properly air-dried. The first and most urgently needed part of this problem has already been worked out, demonstrating the safety of the drying conditions as recommended in the specifications, but the second part has not yet been completely solved, and the experiments are still under way

Visual Inspection Not Sufficient for Airplane Woods

For nearly all commercial uses, it is sufficient that wood be dried without any visible injury or any defect that can readily be detected by inspection For uses in which the strength requirements are more exacting, such as for implements, wagons, etc., a slight reduction in strength, of 10 or even 25 per cent, is seldom of sufficient consequence to be considered a serious defect, provided the wood is satisfactory in other respects. Even when strength is of prime importance, as for tool handles, for instance, a serious consequence, such as a casualty, would seldom result from failure in this respect In fact, to the manufacturers accustomed to handling wood for ordinary purposes, and more especially to the lumber dealers who are used to the commercial grading rules and methods of inspection, the selection of wood for airplanes is like learning a new business It is frequently difficult for them sufficiently to readjust their knowledge of former methods of inspection to appreciate the significance of the subtle defects which render wood unsuitable for airplanes.

The chief invisible defects not covered by ordinary grading rules are brashness, spiral grain, casehardening (internal stresses), and minute checks produced in the drying that have closed up again and become invisible.

Methods of inspection, for the detection of these subtle defects are, as yet, by no means satisfactorily worked out. Moreover, inspectors are necessarily inexperienced in this line of work, as such examinations are comparatively new, and no specific tests are known for determining positively whether a particular piece is suitable or should be rejected. Much depends upon judgment founded on experience, and, as the latter has necessarily been lacking, errors have frequently been made. Inspectors have often become alarmed over one or another class of defects and have thrown out great quantities of valuable material, such as wing beams or propeller woods,

*Specification 20, 500-A for Kiln-Drying Airplane Stock, Air Service, U. S. War Department.

Fig 2 Douglass Fir Wing Beam Stock Ready for the Kilns

which tests to destruction subsequently, conducted with care have shown to be entirely suitable for use

Advance Rot

In this connection, the question of "advance rot" as affecting the toughness of the wood is of great importance. Even where there is apparently no evidence of the actual presence of fungus hyphae, the enzymic action has been known to extend some distance into the otherwise sound wood, altering the chemical condition of the cell walls and causing the so-called "advance rot" This condition is usually accompanied by a discoloration of the wood, but other discolorations of an entirely harmless nature also frequently occur, and the discolorations of certain fungi fade out entirely upon exposure to the air Very little is known concerning this subject and it is now being carefully studied by the pathologists of the Department of Agriculture

No Adequate Direct Tests Have Yet Been Devised

It might be argued that an actual mechanical test is the only accurate means of determining the suitability of a piece of wood for use, but here the difficulty enters that a mechanical test, to be entirely adequate for the purpose, in some cases injures the part and renders it unfit for use A test made within the elastic limit of the material will establish its strength up to the amount of stress imposed, but it does not indicate what will be the behavior of the piece if it is suddenly made to withstand a load considerably in excess of this amount On the other hand, a test made on an adjacent piece of wood fails of its purpose, as the defect may be confined to the one specimen and not occur in the representative piece tested This throws us back upon a visual examination based on the intimate experience of the inspector, which after all may prove to be the most effective way, but, at the present time, is far from satisfactory, and for certain purposes the mechanical test within the elastic limit is probably preferable

The test to maximum load of struts that fall in the long column class is adequate to determine the load carrying capacity of the strut, and the test may be made without any injury to the strut Such tests, however, cannot entirely take the place of visual inspection. Visual inspection is needed in this case to detect defects which, while not affecting the maximum load, would have a tendency to produce failure very early after the maximum load was passed

Suitable Drying Conditions

The accompanying curves give the temperatures and humidities suitable for kiln drying airplane material without injury The length of time shown is only intended as approximate as it will vary greatly in different kilns

In these curves the temperature is in degrees Fahrenheit of the hottest portion of the pile of lumber The relative humidity and the moisture percentage of portions of lumber subjected to these same conditions are also given It is not intended that these curves should represent the continuous conditions at all times, as it would ordinarily be entirely impracticable to fol-

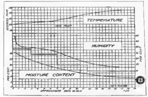

Fig 3 Conditions Suitable for 3-in Spruce Plank Constant Dew Point Method of 115 Deg. Fahr.

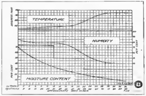

Fig 4 Conditions Suitable for Oak, Black Walnut, Mahogany or Douglass Fir, 1 or 2½ in Thick

low a smooth curve in the regulation of a dry kiln but they represent the maximum temperatures and minimum humidities which should prevail for any considerable time, and a condition which should be approached as nearly as possible. Milder conditions are permissible, but not more severe. Steaming in saturated steam at the beginning of the drying with a temperature not more than 15 deg. Fahr. higher than the initial drying temperature, and combining six hours for every inch in thickness, is permissible and usually desirable for green wood; for previously air-dried wood, eight hours for every inch of thickness may be allowed, with a temperature not over 30 deg. higher than the initial drying temperature. Near the end of the run, the material, if casehardened, should be steamed for not more than three hours, in saturated steam at a temperature 20 deg. higher than the final drying temperature. After steaming the normal drying conditions should be resumed, and the excess moisture added by the steaming should be removed from the lumber. An average dryness of 9 per cent, with an individual variation of from 5 to 11 per cent, is ordinarily required.

For details as to measurements of conditions in dry kilns and tests of the lumber, reference is made to Signal Corps Specification 20,500-A.

Study of Aerology in the Air Services

The establishment by the Navy Department of a school to train men in the science of aerology, as the exploration of the free atmosphere has been called since 1906, marks one of the two steps taken by the Government for the study of this subject, now so necessary to the success of aviation both in a military sense and commercially. The Army has requested that accommodations for fourteen aviators be provided at the school to co-operate in this new study. The second step made by the Government is the establishing of a board comprising two Army and two Navy officers and two representatives of the Weather Bureau who have been working on the problem of meteorological adjustment covering the upper air. In the Army and Navy it is suggested that a system of upper air observation be established and reports transmitted to a central point, where they may be disseminated by telegraph and wireless as is now done in Great Britain. The meteorological adjustment desired is first for the United States and then with Canada and South America. In this connection it will be recalled that when the British dirigible R-34 arrived at Mineola, Long Island, on July 6, on the first trans-Atlantic trip of this type of airship, the meteorological officer of the dirigible stated it was his experience that the weather reports issued by the governmental weather bureaus were absolutely of no use once an airship rose to the great heights at which they now travel, and that aerology was an undeveloped science in so far as practical aviation is concerned. Air Service officers attempting flights for altitude records in our Army have also demonstrated how little we know of meteorological conditions in the upper strata.

The Aerological School maintained at the Navy Air Station, Pensacola, Fla., will have an accession of fifteen enlisted men to start the four months' prescribed course opening on Dec. 1. Six of the students come from the Navy Air Service, three from the Marine Corps and six from the Army Air Service. The class of six with which the school opened is receiving training in aerology preliminary to taking the advance course which will be maintained at the Weather Bureau in Washington, D. C.

M. I. T. Endowment Campaign

FRONT VIEW OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY ON THE CHARLES RIVER, CAMBRIDGE, MASS.

The U. S. Government is doing much of its research along aero-dynamic lines in the Aeronautical Engineering Laboratory at the Massachusetts Institute of Technology. The wind tunnel there is one of the few installations of that kind in the United States and is modeled on the channel built by the National Physical Laboratory at Teddington, England. It consists of a horizontal wooden box, 50 ft. in length and 4 ft. square. At one end a four-bladed propeller revolves up to a speed of 900 r.p.m. for a current velocity of 40 m.p.h. This is driven by a constant speed direct current motor. A speed of 30 m.p.h. has been found to be the best for ordinary testing. An important feature of this tunnel is the remarkably uniform rate of air flow, this uniformity being maintained by means of a motor rheostat used in conjunction with an air-speed gauge.

In the tunnel is a balance which registers the lift, the drift, and the resistance of the models in the uniform air currents. It is a copy of the one at the National Physical Laboratory in Great Britain and its coming to America was considered of such importance that it was given a reception before it left England. In testing a complete model of a plane for "yaw," or rotation about its vertical axis, in flight, or in testing a wing for moment the model is mounted on a channel arm in normal flying position and the moment of rotation determined by means of a calibrated torsion wire.

The Institute is anxious to develop its aeronautical engineering course to a point where it can be included in the general undergraduate curriculum. It is in order to finance developments of this kind that the alumni and friends of M. I. T. are planning a campaign for a $10,000,000 Endowment Fund. The campaign is to last through the fall, but must be successfully terminated before the beginning of the new year if the institute is to receive the $4,000,000 which an unknown benefactor, "Mr. Smith," has promised on the condition that another $4,000,000 be raised in that time. Technology owes her present splendid quarters in a large measure to the generosity of this same "mysterious Mr. Smith," who has already given her $7,000,000. This time "Mr. Smith" has promised to reveal his real name at the close of the campaign and all Technology is awaiting that time with a great deal of interest.

Computations of Airplane Climb

By F. W. Caldwell*

The following assumptions will be made in calculating the climbing rate with a fixed blade propeller.

1. Engine output = 170 hp.
2. Propeller diameter = 8 ft. and A = 50.3 sq. ft.
3. Radiator area = 3.3 sq. ft. Effective area = 50.3 — 3.3 = 47.
4. Velocity of airplane = 120 m.p.h. = 176 f.p.s.
5. Engine speed = 1600 r.p.m. = 26.7 r.p.s.

The calculations are as follows.

In order to compute the thrust assume a propeller efficiency of 79 per cent.

$$T = \frac{550 \times hp \times e}{V} = \frac{550 \times 170 \times 0.79}{176} = 420 \text{ lb}$$

$$v = \frac{T}{AV\frac{\rho}{g}} = \frac{420}{47 \times 176 \times 0.00238} = 21.4 \text{ f.p.s.}$$

$$\text{Slip} = \frac{v}{V} = \frac{21.4}{176} = 12.2\%$$

$$e = \frac{V}{V + \frac{v}{2}} = \frac{176}{186.7} = 94.2\%.$$

We must now determine the value of $\frac{ND}{V}$ and in doing this it may be assumed that the section at 0.75 radius is representative of the propeller as a whole.

$$\frac{ND}{V} = \frac{0.75 \times 1600 \times 8}{60 \times 186.7} = 0.858$$

$$\frac{K_y}{K_x} = 20,\ e_2 \text{ (from Fig. 3)} = 0.865.$$

Then $e = 0.942 \times 0.865 = 0.815$, which is reduced to 80 per cent by the spiral component of the slip stream. (The assumption of 79 per cent in computing thrust is nearly enough correct so that it need not be recomputed.)

$$\text{Output} = 0.80 \times 170 = 136 \text{ hp}$$

The effective pitch angle $\varphi = \cot \dfrac{0.75\pi ND}{V + \frac{v}{2}} = 20.3$ deg.

Assume that the true angle of attack from chord is 0.5 deg. and that blade angle (θ) = 20.8 deg.

Propeller Efficiency Under Climbing Conditions

The following calculations apply to propellers on a conventional-type engine.

Assume rate of climb as 65 m.p.h. = 95.3 f.p.s.
The speed in climbing = 1475 r.p.m.
Assume efficiency = 60 per cent.

$$T = \frac{0.60 \times 550 \times 1475 \times 170}{95.3 \times 1600} = 542 \text{ lb}$$

$$v = \frac{542}{47 \times 95.3 \times 0.00237} = 50.9$$

$$\text{Slip} = \frac{50.9}{95.3} = 53.4\%$$

$$e_1 = \frac{V}{V + \frac{v}{2}} = \frac{95.3}{120.8} = 79\%$$

$$\frac{ND}{V} = \frac{0.75 \times 1475 \times 8}{60 \times 120.8} = 1.22.$$

Effective pitch angle φ = 14.5 deg.

Angle of attack = blade angle — effective pitch angle = 20.8 — 14.5 = 6.3 deg.

$$\frac{K_y}{K_x} = 15.5 \qquad e_2 \text{ (from Fig. 3)} = 0.79.$$

$e = 0.79 \times 0.79 = 62.3$ per cent, which is reduced by the spiral component of slip stream to 60 per cent.

$$\text{Output} = \frac{0.60 \times 1475 \times 170}{1600} = 94 \text{ hp}$$

Before going further to determine the climbing rate let us obtain figures similar to the above for an adjustable pitch propeller. For this assume that

Speed = 1970 r.p.m. during climbing

$$\text{Output} = \frac{1970 \times 170}{1600} = 209 \text{ hp}$$

Efficiency = 55%
Air speed = 65 m.p.h. = 95.3 f.p.s.

$$T = \frac{0.55 \times 550 \times 209}{95.3} = 665 \text{ lb}$$

$$v = \frac{665}{47 \times 95.3 \times 0.00238} = 62.5 \text{ f.p.s.}$$

$$\text{Slip} = \frac{62.5}{95.3} = 65.5\%$$

$$e_1 = \frac{V}{V + \frac{v}{2}} = \frac{95.3}{126.7} = 75.3\%$$

$$\frac{K_y}{K_x} = 20 \qquad e \text{ (from Fig. 3)} = 0.85.$$

$$\frac{ND}{V} = \frac{0.75 \times 1970 \times 8}{60 \times 126.7} = 1.55$$

$e = 0.86 \times 0.753 = 64.7$ per cent, which is reduced by spiral component of slip stream to be 59 per cent.

$$\text{Output} = 0.59 \times 209 = 123 \text{ hp}$$

Comparison of Climbing Rates

Assume
Weight = 1400 lb.
Power required to fly at 65 m.p.h. = 35 hp.

With the Fixed Pitch Propeller

Excess power for climbing = 94 — 35 = 59 hp.

Rate of climb is $\dfrac{59 \times 33\,000}{1400} = 1390$ f.p.m.

With Adjustable Pitch Propeller

Excess power for climbing, 123 — 35 = 88 hp.

Rate of climb, $\dfrac{88 \times 33\,000}{1400} = 2070$ f.p.m.

Gain in rate of climb = 49%

The increasing speed of engine during climbing will have the tendency to overspeed the powerplant while climbing and to allow the speed to become normal in level flight. The desirability of this feature is still open to question.

Calculations of Efficiency During Climbing

The following calculations apply to an adjustable pitch propeller on a constant torque engine.

(1) *At ground level*

$$\frac{\rho}{g} = 0.00238 \qquad A = 104 \text{ sq. ft.}$$

V = 103 f.p.s. Engine output, 445 hp. at 1700 r.p.m.
Assume efficiency = 55%

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* Aeronautical Mechanical Engineer, A. S., S. C., U. S. Army. Paper read before the S. A. E. Convention at Dayton.

$$T = \frac{0.55 \times 445 \times 550}{103} = 1310 \text{ lb.}$$

$$v = \frac{1310}{0.00238 \times 104 \times 103} = 51.4 \text{ f.p.s.}$$

$$e_1 = \frac{V}{V + \frac{v}{2}} = \frac{103}{128.7} = 0.80$$

$$\frac{ND}{V} = \frac{1700 \times 11.5 \times 0.75}{60 \times 138.0} = 1.764.$$

$$\frac{K_y}{K_x} = 16. \qquad e_2 \text{ (from Fig 3)} = 0.720$$

$e = 0.720 \times 0.80 = 0.576$, which is reduced by the spiral component of the slip stream to be 53 per cent.

Output (useful) = 445 × 0.56 = 236 hp.

(2) *At 10,000 ft. altitude:*

$$\frac{\rho}{g} = 0.00178 \qquad A = 104 \text{ sq. ft.}$$

$$V = 118.7 \text{ f.p.s.} \quad \text{(See Fig. 21.)}$$

Output = 445 hp. at 1700 r.p.m.

Assume efficiency = 56%

$$T = \frac{0.56 \times 445 \times 550}{119.7} = 1155 \text{ lb}$$

$$v = \frac{1155}{0.00178 \times 104.7 \times 119.7} = 52.5 \text{ f.p.s.}$$

$$e_1 = \frac{V}{V + \frac{v}{2}} = \frac{118.7}{145} = 0.819.$$

$$\frac{ND}{V} = \frac{1700 \times 11.5 \times 0.75}{60 \times 153.9} = 1.50$$

$$\frac{K_y}{K_x} = 19 \qquad e_2 \text{ (from Fig 3)} = 0.74.$$

$e_1 = 0.819 \times 0.74 = 60.5$ per cent, which is reduced by spiral component of slip stream to be 57 per cent.

Output (useful) = 445 × 0.57 = 254 hp.

(3) *At 20,000 ft altitude*

$$\frac{\rho}{g} = 0.00119 \qquad A = 104 \text{ sq. ft.}$$

$V = 144$ f.p.s. (See Fig 21.)

Output = 445 hp at 1700 r.p.m

Assume efficiency = 62%

$$T = \frac{0.62 \times 445 \times 550}{144} = 1055 \text{ lb}$$

$$v = \frac{1055}{0.00119 \times 104 \times 144} = 61.7 \text{ f.p.s}$$

$$e_1 = \frac{V}{V + \frac{v}{2}} = \frac{144}{175} = 0.823.$$

$$\frac{ND}{V} = \frac{1700 \times 11.5 \times 0.75}{185 \times 60} = 1.32$$

$$\frac{K_y}{K_x} = 16 \qquad e_2 \text{ (from Fig 3)} = 0.79$$

$e = 0.79 \times 0.823 = 65$ per cent, which is reduced by spiral component of slip stream to 62 per cent.

Output (useful) = 445 × 0.62 = 279 hp.

Engine with Constant Torque

The values of K_y necessary to maintain flight at different speeds and altitudes can be calculated from the formula:

$$\frac{\rho}{g} K_y S V^2 = 3400$$

in which S equals 420, so that

$$K_y = \frac{8.1}{\frac{\rho}{g} V^2}$$

These values of K_y are given in the following table:

M.P.H.		40	60	80	100	120	140
F.P.S.		58.7	88.0	117.3	146.7	176.0	205.3
Altitude, Ft.	$\frac{\rho}{g}$						
0	0.00237	0.396	0.441	0.248	0.159	0.110	0.081
2,000	0.00226		0.386	0.262	0.167		
4,000	0.00213		0.461	0.277	0.177		
6,000	0.00201		0.521	0.295	0.187		
8,000	0.00189		0.554	0.312	0.199		
10,000	0.00178		0.586	0.331	0.212		
12,000	0.00167		0.627	0.353	0.226		
14,000	0.00154			0.380	0.242		
16,000	0.00143			0.414	0.263		
18,000	0.00131			0.449	0.286		
20,000	0.00119			0.496	0.317		

The rate of climb can be obtained by computing the thrust and the wing drag. The difference between thrust and wing drag at maximum speed will be the parasite resistance. The parasite resistance for other speeds can be figured from the ratio of the cube of the velocities, and the wing drag by the usual method. From the sum of these two the power required to fly can be computed, and when this is subtracted from the useful power delivered the excess horsepower, and consequently the rate of climb, can be figured.

For 130 m.p.h. (191.7 f.p.s.),

$$\text{assume } K_y = 0.0935 \qquad \frac{K_y}{K_x} = 12.3$$

$$\text{Wing drag} = W - \frac{K_y}{K_x} = \frac{3400}{12.3} = 276 \text{ lb}$$

$$\text{Power delivered to plane} = 0.80 \times 356 = 285 \text{ hp}$$

$$\text{Wing drag hp} = 191.7 \times \frac{276}{550} = 96$$

Assuming engine speed of 1150 r.p.m. at the ground, in climbing at 70 m.p.h. the engine will give 293 hp. Assuming 58 per cent propeller efficiency, the thrust will be

$$T = \frac{0.58 \times 293 \times 550}{103} = 911 \text{ lb}$$

$$v = \frac{911}{0.00237 \times 104 \times 103} = 35.8 \text{ f.p.s.}$$

$$e_1 = \frac{V}{V + \frac{v}{2}} = \frac{103}{120.9} = 0.853$$

SUMMATION OF RESULTS OF CALCULATIONS FOR ENGINE WITH CONSTANT TORQUE

Altitude	0	5,000	10,000	15,000	20,000
Best climbing speed M.P.H.	70	75	81	88	98
F.P.S.	102.7	110.0	118.9	129.1	143.7
Wing drag hp. $= \frac{3400}{K_y/K_x} \times \frac{V}{550}$	44.3	47.3	51.4	54.0	62.3
Parasite resistance, hp. = 168 ρ/g × V^3/1913	30.0	31.7	34.3	38.3	46.6
Total hp. required to fly....	74.3	79.2	85.7	92.3	108.9
Hp. available with conventional type propeller .. .	167.2	178	195	217	247
Excess hp.	92.7	98.8	109.3	124.7	144.1
Rate of climb, f.p.m.	900	960	1062	1210	1400
Time to reach altitude, minutes.		5 2/3	10 2/3	13	16
Hp. available with adjustable pitch propeller at 1700 r.p.m.	256	246	254	263	276
Excess hp	183.3	166.8	168.3	170.7	178.1
Rate of climb f.p.m.	1610	1515	1633	1660	1660
Time to reach altitude, minutes.		3 1/6	6 1/3	9 1/2	12 1/2

$$\frac{ND}{V} = \frac{1150 \times 11.5 \times 0.78}{60 \times 120.0} = 1.38.$$

Assuming a $\frac{K_y}{K_x}$ of 13 for this condition, the aerofoil efficiency will be 67 per cent, and

$$e = 0.67 \times 0.853 = 57\%.$$

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60 Handling trucks for H-16	600.00	Philadelphia, Pa.
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INDEX TO ADVERTISERS

A

Aeromarine Plane & Motor Co. 336
Aircraft Journal 370
Aluminum Co. of America 364
American Propeller & Mfg. Co. 364
American Sash & Door Co. 365
Atlas Wheel Co. 358

B

Baker Castor Oil Co. 365
Barker, F. W. 366
Berling Magneto 366
Boston Auto Gage Co. 364
British and Colonial Aeroplane Co., Ltd. 363
Boeing Airplane Co. 360

C

Curtiss Aeroplane & Motor Corp. 357

D

Daytona Flying Club 282
Doehler Die-Castings Co. 366

E

Ericsson Manufacturing Co. 284

F

Ferdinand, L. W., Co. 367
Farman, H. and M. 252
Flottorp Mfg. Co. 368
Foxboro Co. 366

G

Grand Rapids Veneer Works 367

H

Home Insurance Co. 362

J

Jacuzzi Bros. 366
James and Co., Fred S. 358
Johns-Manville 363

L

L-W-F Engineering Co., Inc. 359
Lansing Stamping & Tool Co. 365
Lewis & Vought Corp. 335

M

Martin, The Glenn L. Co. 334
Maryland Pressed Steel Co. 361
Meyer Mfg. Co., A. J. 366
Multnomah Lumber and Box Co. 365
McGraw-Hill 280

N

New Departure Manufacturing Co. 338
Norma Co. of America 367

P

Packard Motor Car Co. 370
Park Drop Forge Co. 360
Pioneer Instrument Co. 368
Princeton Flying Club 282

R

Ranels, William G. 231
Roebling's Sons Co., John A. 367
Rolls-Royce, Ltd. 371

S

Simon, Emil J. 367
Simon, Harry M. 367
Sturtevant Co., The B. F. 359

T

Thomas-Morse Aircraft Corp. 361

U

United Aircraft Engineering Corp. 363
U. S. Aero Exchange 367
U. S. Metal Cap and Seal Co. 362
U. S. Navy 368
U. S. Rubber Co. 372

V

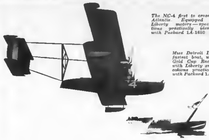
Veeder Manufacturing Co. 364
Vought, Chance M. 385

W

Wakefield and Co., C. C. 278
West Virginia Aircraft Co. 365
Wittemann-Lewis Aircraft Co. 366
Wyman-Gordon Co. 337
Williams & Co., J. B. 368

Z

Zenith Carburetor Co. 367



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